EXECUTIVE SUMMARY

This report documents the results of an IV&V engineering analysis of TRW study 94-7 on TDRSS "Bent Pipe" Operation. The objective is to assess the completeness and validity of the TRW study and determine if it provides an adequate basis for the Government to make a decision on implementation of a "bent pipe" capability between the White Sands Complex and a remote EDOS Central Processing Facility.

The TRW study uses viewgraph presentation materials to convey the results of the analysis. This presentation approach gives only a sketchy view of the analysis process and focuses primarily on the results of the analysis. This makes it difficult or impossible to understand the analysis process and to validate the conclusions that were reached.

Early in the study a set of basic functional allocations are made that drive the overall TRIF /CPF architecture and operations concept. The study does not provide the analysis details, or a comparison with alternative approaches, to convince the reader that the functional allocations are appropriate. The choices made are not substantiated through a rigorous process which documents the engineering analysis. Additionally, the study fails to look at a number of alternatives that might simplify the TRIF and possibly reduce cost. The option of placing FL and real-time RL functionality at the CPF should have been pursued and the cost and technical implications investigated. Likewise, the option of doing rate-buffering at the TRIF to reduce the TRIF to CPF link bandwidth requirements should have been studies. Other trades regarding the allocation of DCF functionality and possible elimination of the LOPF should have been pursued.

The study provides detailed information on the facility impacts of the TRIF, the hardware additions, deletions, and relocations, and the O&M staffing impacts. It also presents a summary of the requirements changes needed for the TRIF but does not consider basic functional or performance requirement changes which could facilitate a "bent pipe" architecture.

Cost information is only provided as a bottom line dollar value delta for the "bent-pipe" approach compared to the baseline EDOS architecture. Separate hardware and software cost deltas are not provided. Hardware and software cost changes are not broken out at the level of hardware and software components. Furthermore, cost was apparently not considered in making many of the key engineering trades. After the trade decisions were reached, the cost delta was computed.

In summary, the study is not comprehensive, and does not provided the detail needed to substantiate the conclusions reached. It does not provide an adequate basis for NASA to make a decision on a TDRSS "bent pipe" operation.

1.0 CUP REPORT 94-7 REVIEW

1.1 INTRODUCTION

The purpose of this report is to provide an engineering analysis of the TRW Contract Understanding Period Study number 94-7, TDRSS "Bent Pipe" Operation. The text for Task Assignment 94-7 reads as follows:

TDRSS "Bent Pipe" Operation

The contractor shall assess the impact of providing an interface between the TDRSS ground terminal at White Sands and a consolidated EDOS facility in Fairmont, WV. This analysis shall identify impacts to the baseline EDOS architecture, existing external and internal interfaces, changes to the negotiated baseline functions in terms of effort, material, and ODC. In addition, the contractor shall assess the feasibility and impacts on the DPF facility and develop a preliminary equipment layout. The contractor shall report on the implementation schedule, including integration, testing, and transition to operations activities, impacts vs. The baseline schedule. The contractor shall analyze existing EDOS requirements against the consolidated facility in WV and identify either external dependencies or requirements that require modification.

The objectives of this analysis are to answer the following questions:

1. Does the study address all elements of the task SOW? Do they answer all the questions?
2. Are the assumptions valid?
3. Does the study identify all of the technical and cost impacts?
4. Does the study consider requirement changes that would be appropriate?
5. Are the answers valid? Can the derivation of the answers be validated?
6. Should the study have addressed additional or different topics?
7. Does the study provide an adequate basis for NASA to make a selection?

1.2 METHODOLOGY AND APPROACH

The initial step in the methodology was to define the objectives for the analysis. This resulted in the 7 questions listed in Section 2. The analysis effort was structured to correspond to the Task Assignment. The task assignment was parsed into a set of sentences and phrases. These Task Assignment elements are given in bold print in Section 4 to introduce the analysis results in each area. The study report charts were mapped to the Task Assignment elements to determine if all aspects of the Task Assignment were covered (question 1). Then, for each element of the Task Assignment we assessed if the study results are valid and if the results can be validated *based on the information presented* (question 5). In parallel with the validity assessment the assumptions were reviewed, completeness of cost and technical impacts and possible requirement changes were evaluated. On completion of the element by element analysis, we looked at the study report as a whole to see if additional topics should have been considered and if the study provides an adequate basis for selection of an alternative by NASA.

In the analysis below [n] is a reference to chart n of the TRW report.

1.3 RESULTS

The contractor shall assess the impact of providing an interface between the TDRSS ground terminal at White Sands and a consolidated EDOS facility in Fairmont, WV.

The assumption in [6] that all EOS satellites use TDRSS for all data services may not be valid. After the EOS-AM1 spacecraft the high rate down link data for later EOS spacecraft will probably be via X-Band ground stations.

The study does not fully consider DSN, WOTS, and GN.

This analysis shall identify impacts to the baseline EDOS architecture,

A key assumption of the study is that forward link and low rate return link processing must be done at the TRIF at WSC. The option of using Nascom/Domsat is not explored [6]. Can the use of Nascom/Domsat eliminate the need for EDOS forward link functionality at WSC? Are any operational CCSDS missions using Nascom/Domsat? What would the latency be if Nascom/Domsat were used? If real time FL and RL data processing is infeasible at WVA CPF the report should demonstrate that it is true. What are the cost trades between placing these functions at the CPF versus at the TRIF?

The TRIF architecture assumes a full high rate Ecom link from the TRIF to the CPF. This means a 150 Mb/s bandwidth link. The cost for this high rate link belongs to Ecom and therefore does not show up in TRW's estimate of the cost of the "bent pipe" operation. A key trade is needed between the total cost of the proposed approach and an alternative where the TRIF does rate buffering and lowers the bandwidth requirement between the TRIF and the CPF. This may be partially out of scope for TRW but is needed by NASA to fully evaluate the "bent pipe" operation option.

[8] shows a top level system diagram with additions and deletions at the TRIF and additions at the WVA CPF. It is not stated which baseline these additions and deletions are against (presumption is the baseline DIF at WSC and the DPF at WVA, is this correct?)

Appendix A gives architecture diagrams for baseline and alternative cases.

What level of input schedule coordination between TRIF and CPF Data Capture analysts is needed [9 and 10]? Does it go beyond awareness of the NCC/TDRSS and spacecraft schedules?

Why is output scheduling for rate buffered and production data mentioned in [10]? Is this a reallocation of a DIF function to the CPF or a new requirement resulting from the TRIF-CPF architecture?

It is not apparent in [11] why providing a real-time link quality analysis function at WSC permits the EOC to adjust on-board recorder usage.

Could the need for scheduling the proposed high rate Ecom link from WSC to WVA (to resolve conflicts between TSS and LOPF usage) be resolved by use of a second link which is switched or dial up [11, 12]? Even though there is no requirement for concurrent retransmission with live mission downlink, which is less expensive, scheduling one line or having a second switched line for retransmissions? Or could the scheduling interface be as simple as a phone call from CPF to TRIF asking for the retransmission? Another consideration of allowing simultaneous LOPF playback with real time downlink is the need to have a separate LOPF recorder to catch the downlink while the first recorder is playing back the old data. Does the proposed solution have only one recorder at TRIF LOPF? What is availability of the TRIF to CPF Ecom link for high rate data? What is availability of the high rate RL transfer function? How often will the high rate RL transfer function be unavailable? Has the alternative of mailing LOPF tapes from the TRIF to the CPF been evaluated? How often would retransmission be required and would mailing media present a significant performance penalty overall? This could simplify the LOPF function.

What would be lost if the high rate data was sent from TRIF to CPF without collecting statistics [11]. How much hardware would be saved? What extra costs would be incurred for failure analysis? What requirements would not be met?

[12, 13] shows low rate DCF and LOPF at TRIF and high rate DCF at CPF. The approach of using DCF high rate data capture at TRIF instead of LOPF is not explored or explained. What is the cost trade between the proposed option (LOPF and low rate DCF at TRIF and high rate DCF at CPF) versus just placing the high and low rate DCF at the TRIF and eliminating the LOPF? Is the proposed approach the least expensive? A technical trade study is provided in [16 - 18], but no cost information is provided. The two negatives against option 2 (high rate DCF at the TRIF) are not explored fully. How critical is the need for capture at CPF for use in fault isolation?

LOPF Trade option 1 [19] (the recommended approach) says a high bandwidth tape device is an all COTS solution and reflects baseline equipment for data capture. However, [22] says that LOPF hardware additions include a variable rate buffer and high speed tape drive. Does this mean that additional units of the baselined variable rate buffer and high speed tape drive are required?

This analysis shall identify impacts to the existing external interfaces

[29] lists impacts to baseline external interfaces. [6] states the assumption that EDOS supports migration from Nascom/Domsat to Ecom ground transport. But, [29] says Ecom is to provide a scheduling interface for Domsat/terrestrial lines. This appears to be inconsistent.

[29] says the User / Customer interface for rate buffered data will be from the CPF. Since the rate buffered data will be delivered by Ecom, what impact will this have on the User/Customer?

[15] adds a TRIF function for TRIF Interface to NCC. [32 - 33] and Appendix D provide an NCC interface architecture trade. The NCC interface trade does not clearly substantiate the proposed approach. What would the cost and performance penalty be for NCC to CPF interface only? What would the cost and performance penalty be for NCC to TRIF interface only? How do these options compare to the cost and performance of the dual interface approach recommended? How

do other missions handle the NCC real time TSS message interface requirement? Do they have facilities at WSC to support this?

This analysis shall identify impacts to the internal interfaces,

[30] lists 5 impacts to baseline internal interfaces. Impacts seem to be listed against the CPF baseline not the DIF/DPF baseline. The impacts are described in terms of functions, not internal interfaces.

This analysis shall identify changes to the negotiated baseline functions in terms of effort, material, and ODC.

Hardware modifications for the TRIF - CPF approach compared to the DIF - DPF baseline are itemized in [21-27]. Cost per item information is not provided.

[28] lists 6 modifications to baseline software which, taken together, adds 11,000 SLOC. Appendix E gives the SLOC additions in a table. The table identifies the function and CSC affected and gives the purpose of the modification. No dollar costs are given for the itemized software changes.

[37] gives cost delta summary (compared to baseline distributed architecture) The TRIF - CPF approach adds 2.7M in hardware and software to implement. It reduces operations staffing by 5 people. The added costs for high rate lines between WSC and WVA not included. Increased capabilities for Ecom not included. The cost change is not broken out to the individual hardware and software item costs or even to an aggregate hardware cost and an aggregate software cost.

In addition, the contractor shall assess the feasibility and impacts on the DPF facility and develop a preliminary equipment layout.

[35] provides facility requirements for floor space, power and HVAC at TRIF, CPF and SEF. The chart compares baseline, proposed and available quantities of space, power and HVAC. No facility problems are identified.

Appendix B [52-56] gives facility layouts at TRIF, CPF and SEF. These layouts are done in the same manner as in study 94-2 and provide adequate detail.

The contractor shall report on the implementation <u>schedule</u>, including integration, testing, and transition to operations activities, impacts vs. the baseline schedule.

[36] says that the implementation schedule is not impacted for integration, testing and transition to operations. Absolutely no details are provided to substantiate this.

The contractor shall analyze existing EDOS requirements against the consolidated facility in WV and identify either external dependencies or requirements that require modification.

[38-40] and Appendix F describe changes required to restructure the F&PS for the TRIF/CPF architecture. External dependencies are given as impacts on external interfaces. No changes to basic functional or performance requirements are considered.

The study should have determined the loop delay latency that would result from placing the forward link and low rate return link services at the CPF. Then a trade off of the added delay versus the cost of these functions being located at the TRIF could have been made.

The study should have considered the alternative of rate buffering the high rate data sent from the TRIF to CPF. This would reduce the cost of the Ecom link between the TRIF and the CPF and possibly make it a desirable architectural choice.

Other

[34] and Appendix C address Operations staffing impacts (not asked for in Task Assignment) Overall operations staffing decreases from 49 to 44. Staffing changes are given in terms of specific positions, shifts and FTEs. In addition, rationales are given for the staffing changes. The information provided is adequate to understand and validate the staffing changes proposed.

1.4 CONCLUSIONS AND RECOMMENDATIONS

The TRW report is in viewgraph format except for the appendices. While this format is convenient for presentation purposes it is not adequate to convey the supporting details needed to substantiate the conclusions they reach. In many cases, key conclusions cannot be validated based on the information presented. The study report should be done in normal document format, should investigate alternatives as mentioned above and should provide the engineering detail required to support the conclusions reached.

1. Did the study address all elements of the task SOW? Did they answer all the questions?

All areas of the Task Assignment were addressed but many were not covered in sufficient depth.

2. Are the assumptions valid

The assumption in [6] that all EOS satellites use TDRSS for all data services is not valid. After AM1, the high rate down link data will probably be via X-Band ground stations.

[6] The assumption that real-time forward link (FL) and low rate RL data processing must remain at WSC is not sufficiently supported. (This is listed as an assumption in this study but was a conclusion reached in study 94-2.) This position may be correct but needs to be substantiated. It should not be an assumption but should be treated as an alternative and evaluated in greater detail.

3. Did the study identify all of the technical and cost impacts?

The study itemized the hardware and software changes resulting from the "bent pipe" approach. In general, cost impacts are not included in making the key architecture trades. The choices are made on technical grounds, then the cost impact of the final configuration is presented. Even if one accepts the proposed configuration, the cost impact presented is still inadequate because it is a single, bottom line number without a build up from more detailed data.

4. Did the study consider requirement changes that would be appropriate?

The study addresses requirement changes which are needed to reflect the "bent pipe" approach but does not look for requirement changes which would offset the technical problems encountered. For example, the option of keeping the FL and low rate RL functionality at the CPF is not considered because of the loop delay latency requirement could not be met. The increased latency resulting from placing these functions at the CPF should have been presented.

5. Are the answers valid? Can the derivation of the answers be validated?

The following table summarizes the elements of the study and the adequacy of the information presented in each area. A “no” does not mean that the study result is invalid. It means that the supporting information is inadequate to independently validate the results reported.

Study area	Information Adequacy
Architecture	No
External Interfaces	No
Internal Interfaces	No
Cost	No
Schedule	No
Ext. Dependencies/ Req’ts Mods	No
O&M Staffing	Yes

6. Should the study have addressed additional or different topics?

The study addresses O&M staffing impacts although this was not required by the Task Assignment. The study should have examined a number of alternatives to the architectural choices selected. This would either uncover better alternatives or lend more credence to the selections made.

7. Does the study provide an adequate basis for NASA to make a selection?

Without more detailed engineering rationales for the conclusions reached, plus examination of additional alternatives, the study is not definitive and does not provide an adequate basis for NASA to decide on the ”bent pipe” approach.